

THE URBAN MOUSE, *MUS DOMESTICUS*, AND ITS ROLE IN THE TRANSMISSION OF *TOXOPLASMA GONDII* INFECTION

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Abstract As part of an investigation into the potential public health threats posed by infestations of the urban house mouse (*Mus domesticus*) in the UK, 200 mice were trapped and screened for the presence of a number of zoonotic diseases. Results indicated that none of the mice were infected with *Strongyloides stercoralis*, *Trichuris trichiura*, *Hymenolepis nana*, *Campylobacter*, *Escherichia coli* 0157, *Listeria*, *Shigella*, *Salmonella*, *Yersinia* or *Coxiella burnetii*. Four mice tested positive for *Cryptosporidium*, and two for *Chlamydia*. Forty-two percent were infested with fleas. Serological testing confirmed that 1% of the mice were infected with *Toxoplasma gondii*. When infection was determined by detection of *T. gondii*-specific DNA using the SAG1-PCR, an infection rate of 58.5% was found. This is considerably higher than the infection rates reported by previous authors. Mice (along with most warm blooded animals) act as intermediate hosts of this parasite, but cats are the only known definitive host. The only known definitive host is the cat. Public health importance of *Toxoplasma gondii* lies in its ability to cause serious pathology in certain vulnerable groups, such as pregnant women (e.g. foetal pathology/abortion) and the immunocompromised (e.g. fatal encephalitis). Human infection is via ingestion of food and/or water contaminated with oocysts excreted by cats, by consumption of tissue cysts in undercooked meat and by vertical transmission from mother to foetus. Current approaches to the control of mice in urban areas are discussed in the light of these high infection rates.

Key Words *Mus domesticus*, disease transmission, *Toxoplasma gondii*

INTRODUCTION

The house mouse, *Mus domesticus*, is highly successful in exploiting the human environment and its continued survival and proliferation owes much to its capacity to adapt to life in close association with people and to its nocturnal habits which enable foraging activities to go largely unnoticed (Rowe, 1973; Shenker, 1973). In the UK, house mice tend to live almost entirely inside buildings, increasing the opportunities for direct and indirect contact with people and this poses a potential threat to public health through the diseases they may carry. Whilst urban house mice are known to transmit lymphocytic choriomeningitis (Buchmeier et al., 1980), their role in the spread of disease causing organisms such as *Salmonella*, *Campylobacter*, *Wisteria* and *Toxoplasma* is less clear (Gratz, 1994, Healing, 1991; Konishi and Takahashi, 1987; LeDuc, 1987; Webster, 1996). Carrer et al. (2001) suggested that the presence of rodents in the home may contribute to increased levels of indoor allergens, causing allergic asthma and rhino conjunctivitis. In addition to the risk of spreading disease, the presence of rodent infestation can cause considerable distress and anxiety to individuals living in infested properties (Hekmat, 1987; McNally and Steketee, 1985).

Toxoplasma gondii is an intracellular protozoan parasite capable of infecting almost all warm-blooded animals including humans. The public health impact of *T. gondii* lies in its ability to cause spontaneous abortions and foetal abnormalities, and to induce serious illness in immunocompromised subjects. Cats are the only known definitive host for *T. gondii*, and acquire the infection in one of two main ways: via consumption of infected intermediate host prey or via ingestion of oocysts within their food or water (Dubey and Beattie, 1988). Following infection, a cat may produce more than 100 million oocysts in its faeces, which can remain viable in the environment for over a year (Jackson et al., 1988; Frenkel, 2000). Cats cease shedding oocysts in their faeces approximately 14 days after the initial infection. The prevalence of *T. gondii* infection in cat populations will depend upon the availability of and contact with infected prey species such as small mammals, where infection levels depend upon access to and ingestion of infected oocysts and/or transmission of the infection via a congenital route (Dubey and Beattie, 1988).

As intermediate hosts, humans can become infected by three main routes, horizontally through the ingestion of food and/or water contaminated with oocysts excreted by infected cats, by consumption of tissue cysts in undercooked meat, and vertically via transplacental tachyzoites from mother to foetus. As the infective oocysts excreted by the cat are considered a major source of infection, the advice typically given to vulnerable groups such as pregnant women focuses on the avoidance of contact with cats and cat faeces.

Human toxoplasmosis can range from an asymptomatic episode to chronic and even life threatening illness. Individuals with a robust immune system usually experience a mild and self-limiting illness, although tissue cysts of the parasite may remain present for many years. Women who acquire toxoplasmosis during pregnancy have a 45% chance of transplacentally transferring the parasite to the foetus. In 1992, the incidence of prenatal infection with *T. gondii* in human neonates was estimated as 0.3-1.6 per 1000 births in the UK (Zadik et al., 1995). Effects on the foetus ranged from sub-clinical infection to intrauterine death in 10% of cases (Remington and Desmonts, 1990; Chatterton, 1992).

Experimental infection of the house mouse (*Mus domesticus*) and the field mouse (*Apodemus sylvaticus*) with infective oocysts demonstrated a high frequency of vertical transmission (i.e. repeated transplacental transmission from one generation to the next) (Thiermann, 1957; Beverley, 1959; Remington, et al., 1961; De Roeber-Bonnet, 1969; Owen and Trees, 1998; Marshall et al., 2004). In fact, they are the only hosts where vertical transmission of the parasite is recognised as being an important route, although recent research suggests that this route may also be important in sheep (Duncanson et al., 2001; Williams et al., 2005).

Consequently, *T. gondii* infection levels could theoretically persist within a mouse population in the absence of felid-derived oocysts. This would suggest that within the urban context, mice may act as important intermediate hosts in facilitating the persistence of the parasite. However, few studies have investigated the role of this host in an urban setting and available seroprevalence data suggests that infection rates are low at 1-5% (Franti et al., 1976; Burrige et al., 1979; Smith and Frenkel, 1995; DeFeo et al., 2002).

The main aim of this study was to investigate the potential public health risk of house mice with regard to zoonotic infection, in particular *T. gondii*.

MATERIALS AND METHODS

This study was undertaken following high levels of concern amongst the residents regarding the prevalence of domestic mouse infestations in an urban residential area. The research area in Cheetham Hill, Manchester, UK contained 253 domestic properties and was known to have suffered from chronic mouse infestations for many years. Residents in the study area were informed of the aims and objectives of the research project and were asked to facilitate in the live capture of mice by allowing members of the research team regular access to their properties to place and check live mouse traps. Tracking plates, placed in 202 of the 253 properties in the study area assisted in establishing the location of infested properties in the study area. Positive mouse activity was recorded in 73 households (30%). Live traps were then placed in properties where daily access to check them could be guaranteed. During this phase, 200 mice were caught in 27 properties.

Mice were humanely dispatched using cervical dislocation and blood, brain, kidney, faeces and small intestine samples were harvested. All but the brain samples were sent to the Public Health Laboratory Service for screening. Faecal and intestinal samples were tested by direct microscopy and by culture for three parasites, and for bacterial infections *Campylobacter*, *E. coli* 0157, *Listeria*, *Shigella*, *Salmonella* and *Yersinia*. Blood samples were tested for leptospiral antibodies for all serotypes and the kidneys by immuno-fluorescence for signs of leptospiral organisms. Serological tests were also undertaken to screen for *T. gondii*, *Chlamydia* and *Coxiella*. The brain tissue was screened for the presence of *T. gondii* using the nested polymerase chain reaction (PCR) amplification of the Surface Antigen Gene 1 (SAG1).

RESULTS

Results confirmed that none of the mice were infected with the three parasites commonly associated with house mouse populations (*Strongyloides stercoralis*, *Trichuris trichiura*, *Hymenolepis nana*), *Campylobacter*, *E. coli* 0157, *Listeria*, *Shigella*, *Salmonella*, *Yersinia*, *Coxiella burnetii* or *Leptospira*. Table 1 details the positive tests. Four mice tested positive for *Cryptosporidium*, and two for *Chlamydia*. Forty-two percent were infested with fleas. An interesting result arose in the differences in prevalence for *T. gondii*, depending on the test used. Serological screening confirmed very low levels of *T. gondii* infection (1%, n=192). The PCR test confirmed an infection rate of 58.5%. The mice had been captured in 27 domestic properties and the infection rate within properties was examined and results are presented in Table 2.

Table 1. The zoonoses of the House mouse (*Mus domesticus*) caught from Cheetham Hill Study Site

Diseases/vectors (zoonoses)	Positive	Negative	N	Not tested / missing	Valid proportion positive (%)
Fleas	84	114	198	2	42.4
<i>Toxoplasma gondii</i> (PCR)	117	83	200	0	58.5
<i>Toxoplasma gondii</i> (serology)	2	190	192	8	1.0
<i>Cryptosporidium</i>	4	195	199	1	2.0
<i>Chlamydia spp.</i>	1	183	184	16	0.5

Table 2. Mouse catch and % prevalence of *T. gondii* infection per block/house.

Block / House No.	Total caught	% +ve	Block / House No.	Total caught	% +ve	Block / House No.	Total caught	% +ve	
B1	1	5	B5	10	5	B8	20	10	
	2	5		11	1		0	21	3
	3	6		12	19	53	B9	22	10
	4	33	13	5	40	23		3	
	5	17	B6	14	1	100		24	4
	6	2		50	15	13		100	25
B2	7	23	16	1	0	B10	26	1	
B3	8	6	67	17	8		75	27	1
B4	9	1	0	B7	18	7	29		
			19		1	0			

The number of mice caught per property ranged from 1-33 with a mean of 7.4. *T. gondii* infection rates within properties ranged from 0 – 100%, although in five of the six properties (houses 9, 11, 16, 19 and 26) with no positive mice, only one mouse had been caught per property. Propagation of the disease to the definitive host is achieved when mice are predated upon by cats. Separate studies on this population of mice confirmed that mice appeared to be able to move between properties which were attached. The 27 houses were grouped into 10 housing blocks (see Table 1). The pet cat population was established during a resident survey and 32 households in the study area confirmed that they were cat owners. Cats were present in 8 of the 10 blocks (only blocks 5 and 8 did not contain cats).

DISCUSSION

The results of the faecal, intestinal and blood screening revealed a reasonably healthy mouse population posing a relatively low risk of disease transmission to the residents living in infested properties. Almost half of the mice were carrying fleas and further work is being undertaken to identify the species present.

Infection rates for the protozoan parasite *T. gondii* varied depending on the test used. PCR-based detection found high levels of infection (58.5% infected), but low levels using serological detection (1% infected). This phenomenon may demonstrate the importance of vertical transmission of the parasite within this host. Previous studies have indicated that serological detection methods may not be accurate for detection of the parasite when it is vertically transmitted (Suzuki and Kobayashi, 1990; Owen and Trees, 1998), due to the occurrence of tolerance amongst newborn mice. Sixteen of the mice caught during the live trapping phase were pregnant, and the foetuses of these females were screened for *T. gondii* infection. Marshall et al. (2004) found that 75% of these foetuses tested positive for *T. gondii* infection, confirming that vertical transmission was occurring at a high rate amongst this mouse population.

Vertical transmission is an important factor in the epidemiology of the parasite as theoretically it may be able to maintain itself within the mouse population by transmission from mother to foetus. Whilst mice do not pose a direct risk of infection to the human population, they could be an important reservoir for the parasite, enabling it to survive until such times as a cat is introduced and the cycle is completed. High risk groups such as pregnant women could then be infected by handling cat faeces. Effective control of the infection would therefore require a rigorous mouse control strategy to eradicate the house mouse reservoir.

In other work investigating the population structure of these mice, it was found that each block of houses represented separate populations or 'breeding units'. This confirmed that mice were able to move freely between properties within a block which is important when considering their role as reservoirs for *T. gondii*, as it means that there is a greater chance for mice to come into contact with, and potentially infect a felid definitive host residing in any of the properties within a block of housing.

An important next step for this work would be to establish *T. gondii* levels amongst cats and humans in the area. In the UK, mice are currently classed as nuisance pests and local authorities often levy a charge for domestic treatments. Their role in the propagation of *Toxoplasma gondii* infection needs to be taken into account in reviewing whether they can be considered to be nuisance pests in the urban environment.

ACKNOWLEDGMENTS

This study was supported by the Cheetham and Broughton Partnership, Manchester and the authors are grateful for their support throughout the project. Dr Peter Marshall co-ordinated the live trapping of mice and the day to day contact with residents. Mr David Oldbury, Principal Environmental Health Officer at Manchester City Council enabled us to work closely with the pest management services. Alan Langley and Steve Jackson, the pest technicians from Manchester City Council facilitated the collection of live mice in the field. The Public Health Laboratory service at Manchester screened for zoonotic diseases. Our final thanks however must go to the residents of the study area. Their support and patience throughout this the fieldwork was invaluable and we thank them for allowing us to invade their homes.

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